

The World Fossil Fuel Market and America's Energy Future

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Outline of Talk

- US energy history
- Have fossil fuels become increasingly scarce?
 - Evidence from Oil Market
 - Evidence from Natural Gas Market
 - Evidence from “Near Oil” Market
- Will the world ever run out of fossil fuel?

1 BTU = heat required to change the temperature of one pound of water one degree Fahrenheit at sea level

Consumption by Source

Figure 5. Energy Consumption by Source, 1635-2001

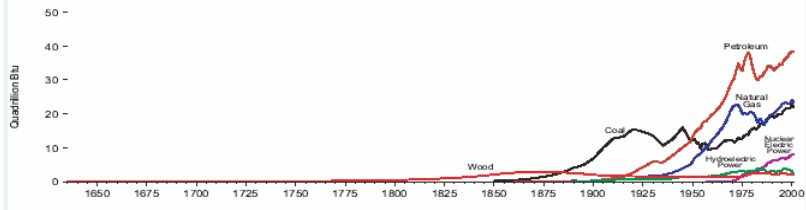


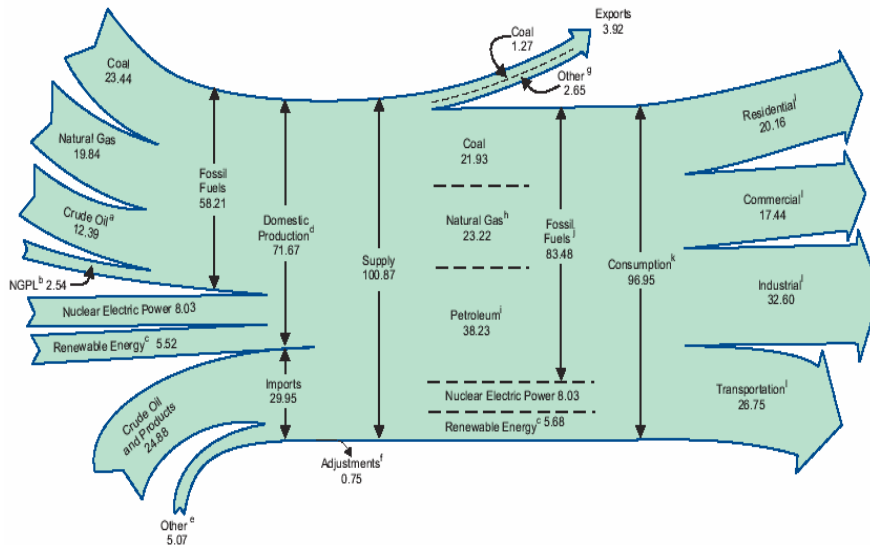
Figure 2. Energy Consumption per Person



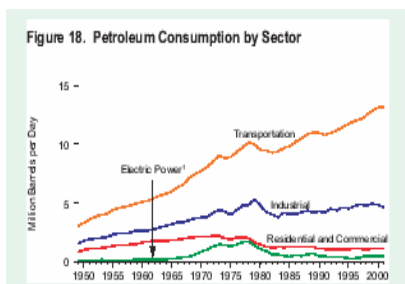
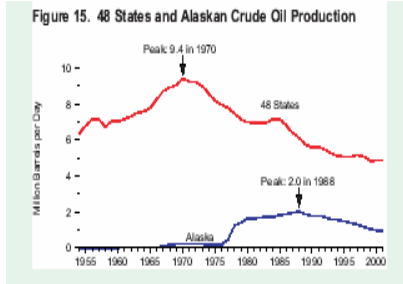
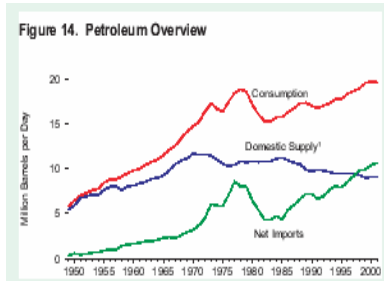
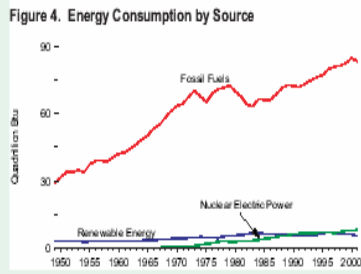
Figure 3. Energy Use per Dollar of Gross Domestic Product



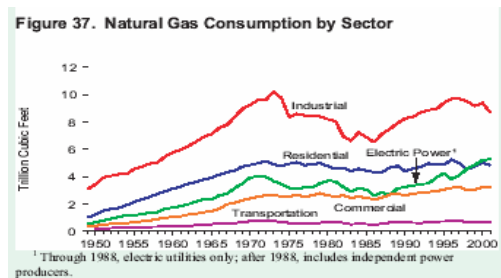
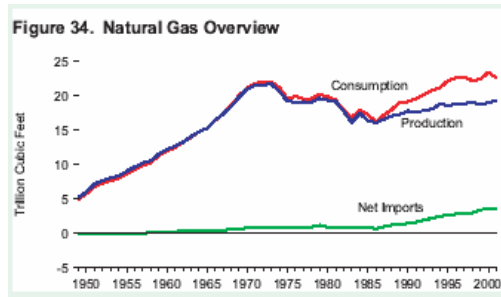
Energy Measured in Quadrillion BTU



Petroleum Sector



Natural Gas Sector



Coal Sector

Figure 38. Coal Overview

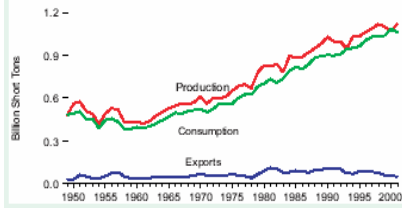


Figure 39. Coal Consumption by Sector

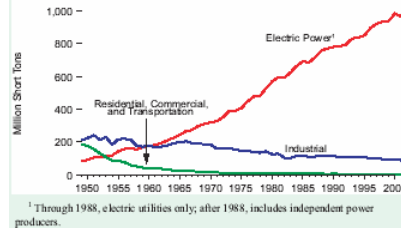


Figure 41. Production by Mining Method

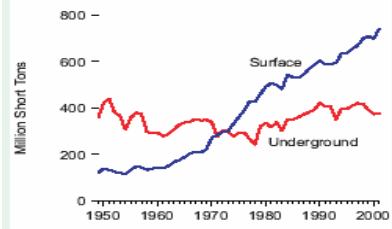
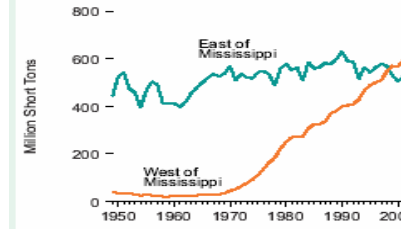


Figure 42. Production by Location



International Energy Sector

Figure 62. Leading Crude Oil Producers

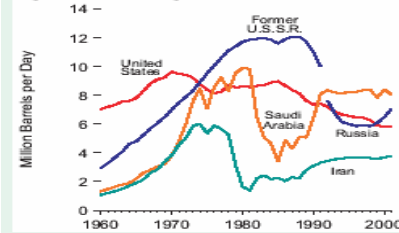


Figure 59. World Primary Energy Production by Source

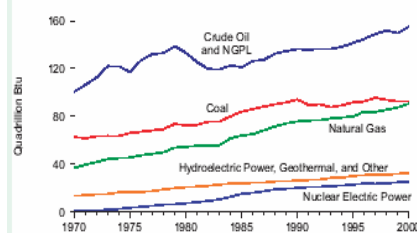


Figure 60. World Primary Energy Production by Region

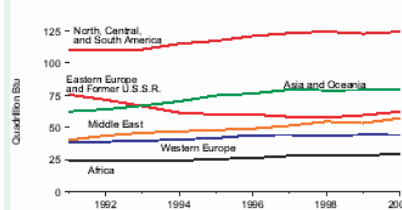
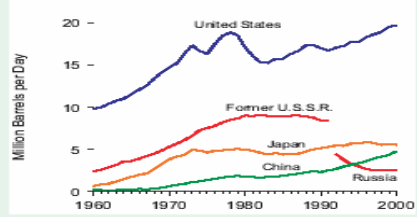
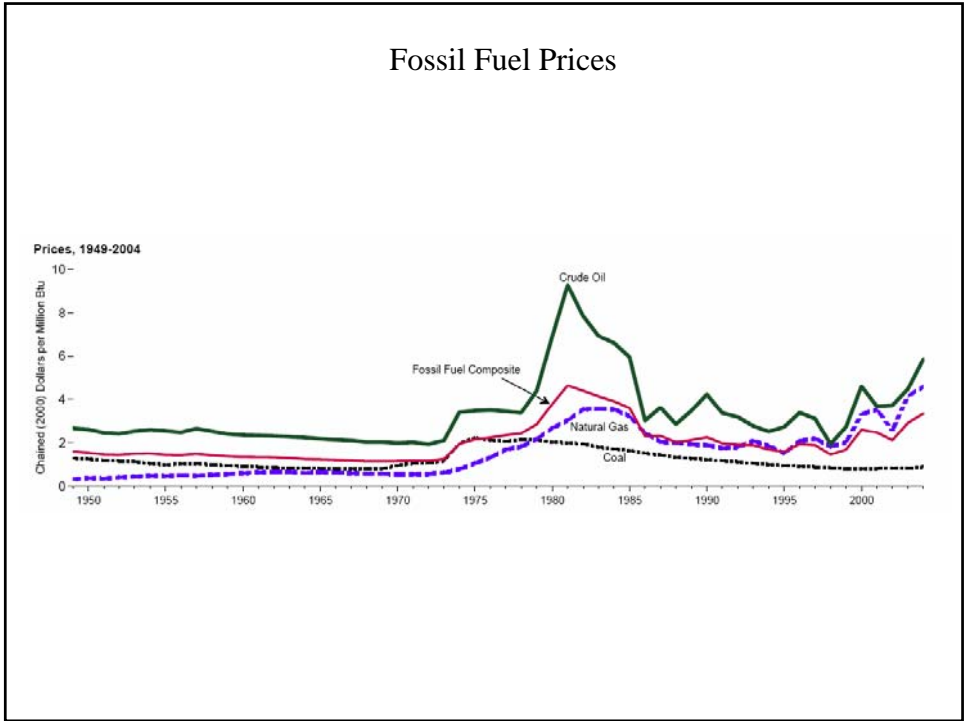


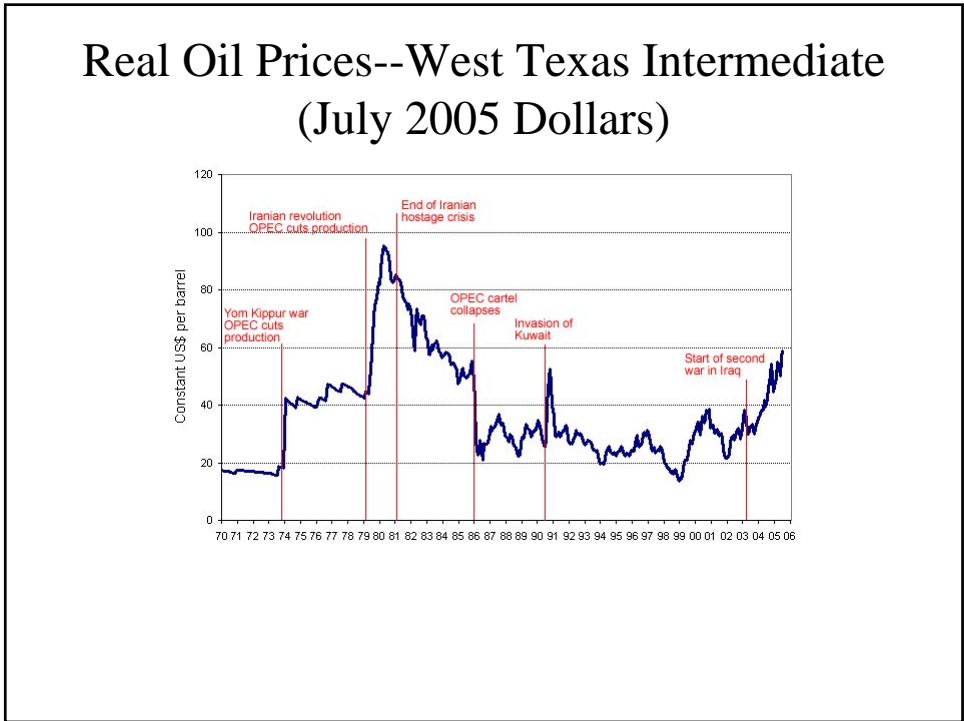
Figure 63. Leading Petroleum Consumers



Fossil Fuel Prices



Real Oil Prices--West Texas Intermediate (July 2005 Dollars)



World Oil Market

- Falling real price of oil since 1979
- Real price increase starting in 2002
- Real price still substantially less than in 1979
- What explains price increase since 2002?
 - Will these higher real prices persist?
- Is the world running out of fossil fuels?

Just What are Fossil Fuel Reserves?

- Estimate of resource that is recoverable using existing technology at pre-specified price
- Example—European Coal
 - Before 1800, concern expressed that Europe would run out of coal
 - Billions of tons of coal left in ground in Europe
 - Not economic to extract and burn given current oil and natural gas prices
- Technological change continually occurring in exploration, extraction, and recovery of oil, natural gas, and other fossil fuels

Just What are Fossil Fuel Reserves?

- In 1875, John Strong Newberry, Chief Geologist of State of Ohio predicted rapid depletion of oil
 - Similar claims continue to present time
- While it cannot be denied that oil and natural gas reserves are being consumed
 - Technological change rapidly adding to reserves
 - “Near oils”—Alberta oil sands
- Continual competition between technological change and depletion of oil and gas reserves
 - Until recently technological change appears to be winning

Don't Bet Against Innovation

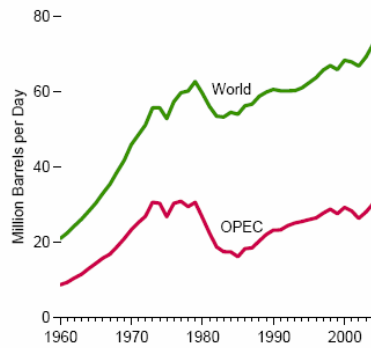
- In 1980 Julian Simon (economist) bet against Paul Ehrlich (biologist) that any basket of 5 metals (chosen by Ehrlich) worth \$1000 in 1980 would be worth less in real dollars in 1990

Metal	1980 price (1980 dollars)	1990 price (1980 dollars)	Percentage change
Copper (195.56 lbs.)	\$200	\$163	-18.5%
Chrome (51.28 lbs.)	\$200	\$120	-40%
Nickel (63.52 lbs.)	\$200	\$193	-3.5%
Tin (229.1 lbs.)	\$200	\$56	-72%
Tungsten (13.64 lbs.)	\$200	\$86	-57%

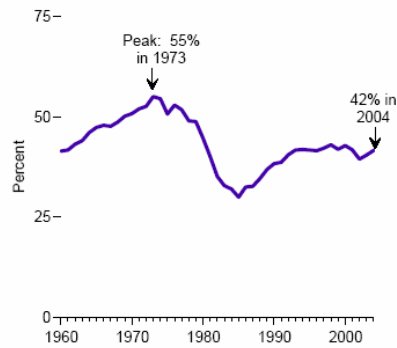
- In 1990, Ehrlich lost the bet and paid change in price of \$576.07 to Simon

Explaining the Recent Real Price Increase (World Oil Production)

World and OPEC, 1960-2004

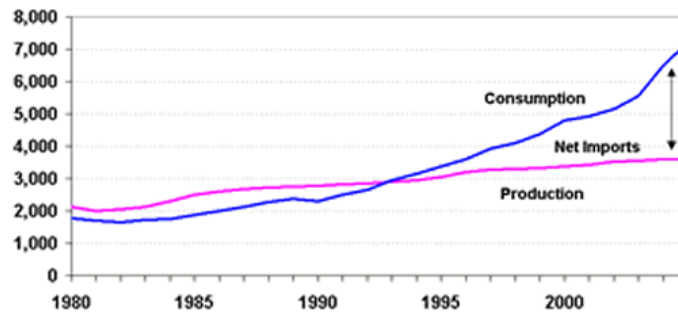


OPEC's Share of World, 1960-2004



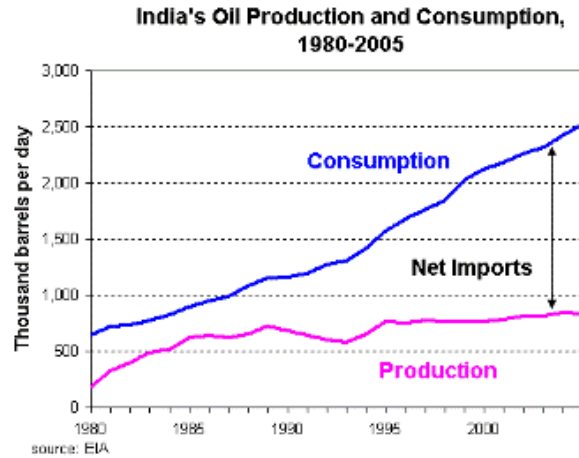
Explaining the Recent Real Price Increase

China's Oil Production and Consumption, 1980-2005 (thousand barrels per day)



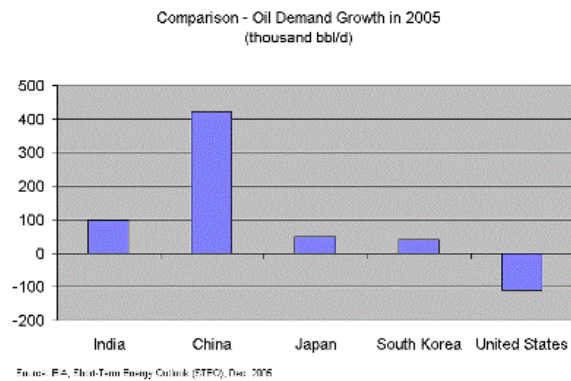
According to US EIA, China accounted for 40% of world oil demand growth over past 5 years
1 million barrel per day growth from 2003 to 2004

Explaining the Recent Real Price Increase



Consumption growth in India has also accelerated recently

Explaining the Recent Real Price Increase



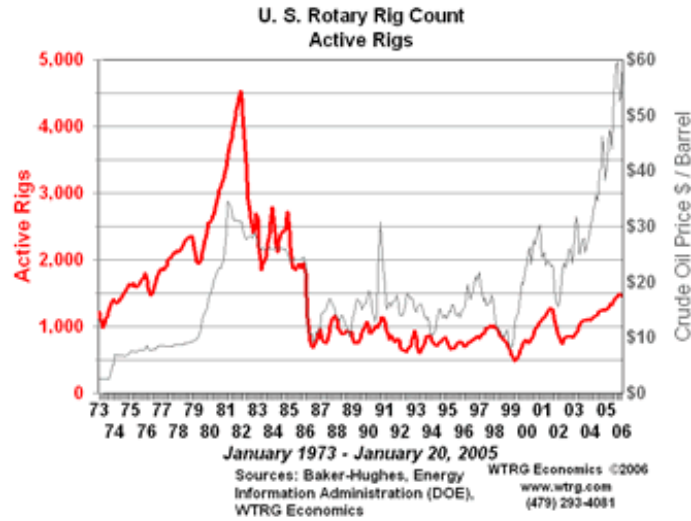
Is it Just About Supply and Demand?

- Current supply planned for industrialized country demand growth
 - Reduced domestic supply due to Hurricane Katrina
- Much more rapid demand growth in China and India occurred
 - Due in part to below world-pricing of oil domestically
- Short-run supply growth relatively constant and unexpected rapid demand growth
 - Substantially higher real-price of oil

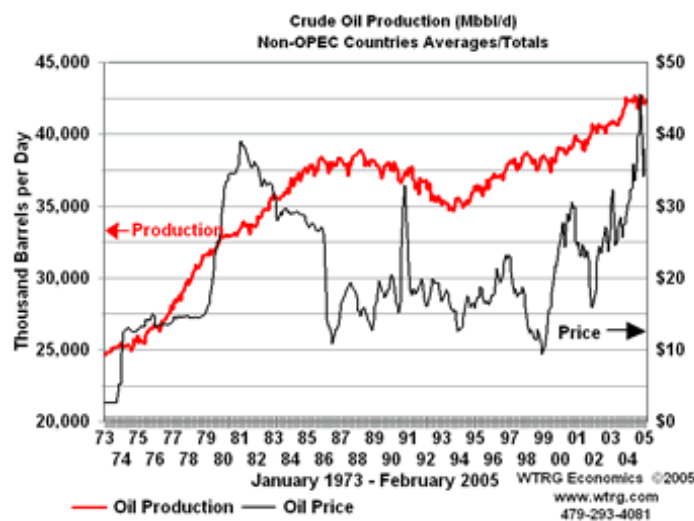
OPEC—A Poorly Enforced Cartel

- Much easier to maintain an agreement to raise prices above competitive levels with unexpectedly high demand
 - Particularly if production is subject to capacity constraints
- Sustained period of extremely low real oil prices during mid-1980s to early 2000 led to very little exploration and drilling activity for oil or natural gas

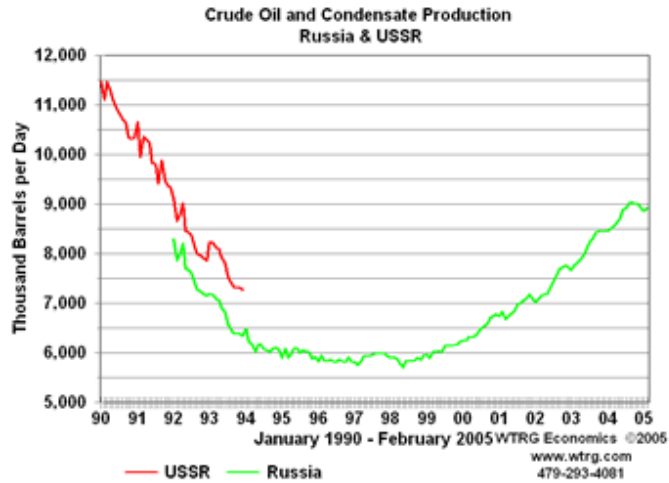
The Oil Boom and Bust (and Boom?)



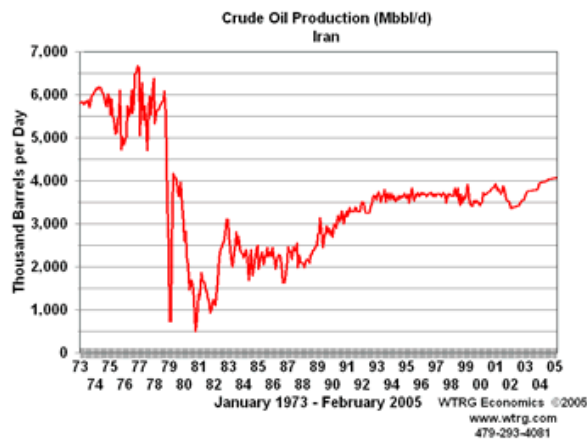
How Competitive Suppliers Respond to Higher Prices



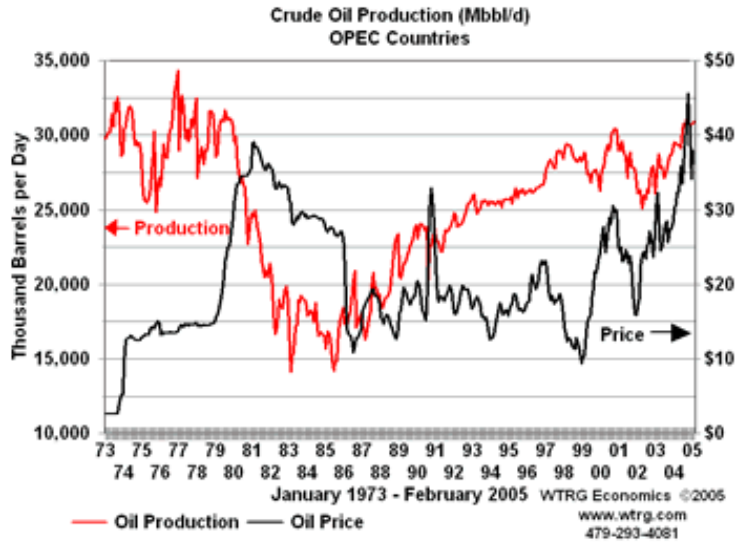
How Competitive Suppliers Respond to Higher Prices



How Suppliers with Market Power Respond to Higher Prices



How Suppliers with Market Power Respond to Higher Prices



Exploration by Suppliers with Market Power

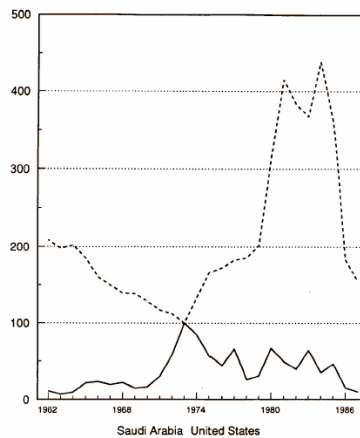
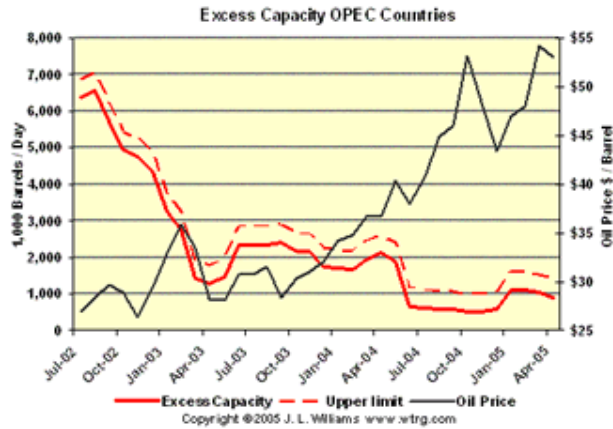


Figure 2 Number of oil wells drilled in the United States and in Saudi Arabia, using 1973 = 100. Source: Ref. 30, and previous August issues for respective years (annual international review).

Output Withholding to Increase Price

How Market Power is Exercised



Explaining Oil Price Fluctuations

- Nominal oil price increases have little to do with true scarcity
 - More to do with ability of members of OPEC to withhold output to drive prices up
- To maintain higher prices, cartels must pass up unilaterally profit-maximizing sales at very high prices to maintain jointly profitable prices
 - Given all other members of cartel produce at reduced cartel output, it is unilateral profit-maximizing for each cartel member to produce more
 - Cartel members find resisting this urge to deviate difficult because the government of these countries need oil revenues
- Fortunately for oil-consuming world, most OPEC countries are extremely dependent on oil revenues
 - Result: Defections from cartel output levels frequent
- Saudia Arabia, as largest producer, attempts to maintain coordinated output levels

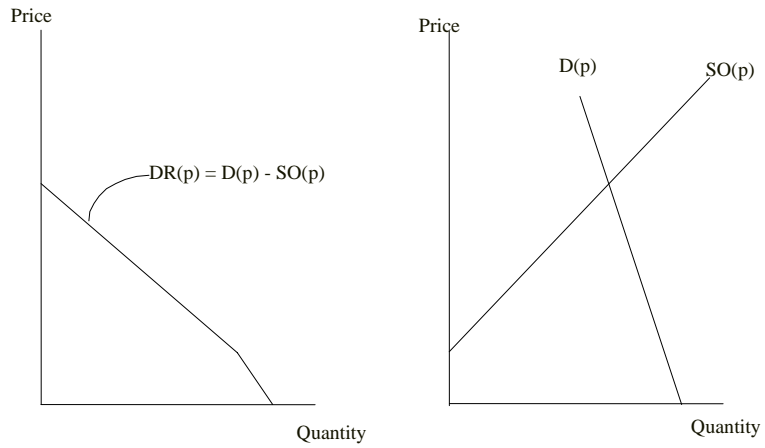
Are We Running Out of Fossil Fuel?

- People with the money don't think so
 - New York Mercantile Exchange runs a futures market for oil
 - Futures contract—Purchase right to delivery of oil at a future date
 - June 2008 contract—Buy right to one barrel of oil delivered in June 2008
 - Futures contracts out to 2011 all say price of oil will be less than \$70 per barrel
- If owner of oil believed prices in future would be extremely high relative to today there is a profitable intertemporal arbitrage opportunity
 - Say \$200/bbl in 2007 versus \$60/bbl right now
 - Hold resource in ground instead of producing now
- If everyone does this, it will drive up price now and reduce price in future
 - Owners of oil reserves always have this option
 - Powerful force to ensure that we do not run out of oil unexpectedly
- OPEC harms this process by creating periodic artificial scarcities of oil when they are able to coordinate on output levels

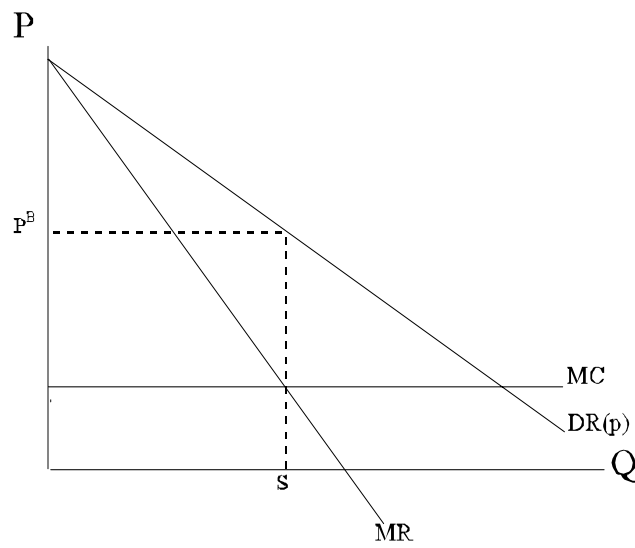
Dealing with OPEC's Destabilizing Actions

- Dealing with OPEC is no different from how consumers should deal with any other supplier or group of suppliers with market power
- Increase elasticity of residual demand faced by OPEC
- Consumers must have the ability to say no to higher oil prices by OPEC
 - Modern society needs energy to prosper
 - Flexibility in demand needed to limit OPEC's market power

Residual Demand Curve faced by Firm



Pricing to Maximize Profits Subject to Residual Demand



Limiting OPEC's Market Power

- Increase number of substitutes for OPEC oil
 - Natural gas and oil sands
 - Fuel switching capability in oil-using capital stock
 - Brazil's solution to high fossil fuel prices is cars that can burn ethanol (from sugar cane) and gasoline
 - Increase use of natural gas in non-traditional sectors
 - Transportation
- Increase extent of integration of world natural gas market

World Natural Gas Market

- Current market for natural gas is a North American market
 - Canada is major source of natural gas imports
- US is a very limited participant in world natural gas market
 - Liquefied natural gas (LNG) is major source of natural gas to Asia and Western Europe
- Besides being the most environmentally friendly fossil fuel (very clean burning), natural gas availability increases alternatives to OPEC oil
 - Increase elasticity of residual demand facing OPEC
 - Limits OPEC's market power over price of oil

US LNG Market

- Four operating LNG terminals on east coast and gulf coast
- No operating LNG terminal on entire Pacific coast
 - From Canada down to Baja California in Mexico
- Since 2000, over 10,000 MW of new gas-fired generation capacity has been brought on line in California, roughly 20 percent increase in California's total installed capacity
 - Neighboring western states are also constructing substantial amounts of natural gas-fired generation facilities—Arizona, Nevada, and Colorado
 - Virtually all new generation capacity build in US is natural gas-fired
- Consensus forecasts of western natural gas prices for 2002-2004 made as late as 2001 were extremely optimistic
 - Current US natural gas prices are \$6/MMBTU to \$7/MMBTU
 - Earlier in winter they were in the range of \$12/MMBTU to \$13/MMBTU

Benefits of Greater Share of LNG in US Energy Mix

- Natural gas can be burned in Combined Cycle Gas Turbine (CCGT) at much greater efficiency than in conventional steam turbine generation facility
 - Roughly 7000 BTU/Kwh heat rate versus 10,000 BTU/Kwh for steam turbine
 - State-of-the art pulverized coal facility has roughly 10,000 BTU/Kwh heat rate
 - Less CO₂ emissions per Kwh of energy produced from using natural gas in CCGT relative to steam turbine with any fossil fuel
- Fewer emissions from burning natural gas relative to oil and coal
 - Significantly less NO_x than oil or coal
 - Virtual no SO_x emissions from gas relative to oil and particularly coal
 - Fewer particulates from natural gas relative to oil and particularly coal

Barriers to Increased Natural Gas Use

- Major barrier is limited amount of natural gas available in North America relative to world supply of natural gas
 - North America has roughly 5 percent of world's natural gas reserves
 - Limited ways to get overseas natural gas to US markets
- Rapidly increasing demand for natural gas throughout US
 - Virtually all new capacity built in North America in natural gas-fired

Barriers to Increased Natural Gas Use

- Difficult to see how future demand will be met at close to world price of LNG without significant expansion of LNG facilities on West Coast
- Post-2000 natural gas prices make a LNG facility very profitable
 - Breakeven prices for LNG are between \$3.50/MMBTU to \$4/MMBTU
 - Prices are currently in the range of \$6/MMBTU to \$7/MMBTU
- Declining costs for liquefaction plant construction, LNG tankers, and regasification facilities over past ten years
- Efficient LNG regasification plant scale would entail roughly 800,000 MMBTU per day capacity
 - Slightly more than 10 percent of California's daily demand

Global Warming Benefits of World Natural Gas Market

- Roughly 5 percent of rest-of-world natural gas flared off versus 1 percent of US natural gas production in 1999
 - Some of flaring off of natural gas due to inability to transport natural gas to market where it can be sold
- Flared-off natural gas still produces CO₂, NO_x without producing any useful energy
- Greater world demand for LNG would likely reduce amount flaring off of natural gas and amount of emissions produced without useful energy being produced
- Amount natural gas flared off in 1999 outside of US was roughly equal to California's annual demand for natural gas
 - Significant global environmental benefits are possible from greater world demand for natural gas

Canada's Role in US Fossil Fuel Future

- Major supplier of oil and natural gas to US
- Alberta has a massive oil sands desposits
 - Canadian Energy Research Institute (CERI) claims they are second only to Saudi Arabia
 - Currently producing 1 million barrels per day
 - Potential to increase to 5 million barrels per day
- Oil sands are financially viable because of higher oil prices
 - \$25/bbl to \$30/bbl is estimated to be long-run breakeven price
- Many other "near oils" become viable if oil prices remain at current levels

If We Aren't Running Out then What Are the Problems?

- Managing market power of OPEC
 - Developing world market for natural gas
 - Developing economical near oils and natural gases
 - Increasing flexibility of fuel-using capital stocks
- Managing technological change in fossil fuel exploration, development and consumption
 - Make more efficient use of what we have

Environmental Concerns

- Fossil fuel consumptions results in
 - Carbon dioxide emissions
 - Coal consumption produces
 - SO₂ emissions and coal ash disposal
 - Natural gas consumption produces
 - NO_x and other particulates
- Cost to reclaim lands after resource deposit is exhausted
- Paying full cost (including environmental cost) of producing and consuming fossil fuel

Environmental Concerns

- Markets can be used to value environmental amenities
 - EPA NO_x and SO_x trading program
 - South Coast Air Quality Management District (SCAQMD) NO_x and SO_x trading program
- Emissions permit prices can be used to cost environmental amenities
- Summer 2000 in California experience with SCAQMD market
 - Suspended for power plants effective February 2001
- Lesson from California--environmental markets under stress are difficult to maintain

Conclusions

- Little evidence world is running out fossil fuels
 - More evidence that OPEC is currently having an easier time exercising market power because of series of fortunate (for them) events
- Integration of world fossil fuel market limiting OPEC ability to exercise market power
 - Developing LNG and near oils and natural gas
- Real problem—Managing environmental concerns associated with increased fossil fuel consumption

Questions/Comments
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